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# Link Budget Design in Land - Atmospheric Communication Links accounting for Buildings' Overlay Profile

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This work is based on recent research on link budget design in wireless land-atmospheric communication links. We account for the effects of shadowing and fading phenomena caused by buildings' overlay profile, their density and spatial distribution above the terrain. The prediction of total pass loss accounts for effects of gaseous structures attenuation and scattering, hydrometeors (rain, snow and clouds) absorption and attenuation, turbulent structures fast fading on radio signals passing atmospheric channels with fading. Additionally, based on the physical-stochastic approach [1], the effects of fading - slow (shadowing) and fast (movements of vehicles), were computed as a sufficient impact in link budget design.

We show that the main effects in link budget design are the buildings' overlay profiles, their density and spatial distribution above the rough terrain with respect to various elevations of stationary ground-based and moving/flying subscribers. We developed an optimal algorithm for predicting the total pass loss for various meteorological situations occurring in the real atmosphere at different heights, for various frequencies of radiated signals, and for different terrestrial channels, mixed residential, sub-urban and urban with various buildings profiles, their density and spatial distribution around the moving and stationary subscriber antennas.

Finally, an advanced approach on how to evaluate and estimate effects of attenuation, absorption, scattering and fading of radio signals propagating in the various land-atmospheric channels in different meteorological conditions, and various types of built-up terrain (mixed residential, suburban and urban) is proposed. Part of the results are shown in Table 1 below.

**Table 1.** Pass loss component impact on link budget

| Parameter | Link budget in the land-atmospheric link [dB] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $f = 2.4\,\text{GHz}$ | | | | $f = 3.3\,\text{GHz}$ | | | | $f = 5.2\,\text{GHz}$ | | | |
| height | 1km | 5km | 7km | 10km | 1km | 5km | 7km | 10km | 1km | 5km | 7km | 10km |
| Freespace loss | 120.09 | 121.02 | 121.78 | 123.06 | 122.861 | 123.787 | 124.55 | 125.829 | 126.811 | 127.737 | 128.5 | 129.779 |
| Cloud loss $\cdot 10^{-3}$ | 17.5 | 3.9 | 3 | 2.5 | 33 | 73 | 57 | 46 | 82 | 18.2 | 14.2 | 11.5 |
| Molecular loss $\cdot 10^{-3}$ | 72.7 | 80.9 | 88.3 | 102.3 | 78.1 | 86.9 | 94.9 | 109.9 | 90.8 | 101 | 0.110.3 | 127.8 |
| Rain loss $\cdot 10^{-3}$ | 23.8 | 25.8 | 27.7 | 31.4 | 47.8 | 51.2 | 54.8 | 62.1 | 290.7 | 311.9 | 332.3 | 372.5 |
| Fast fading (turbulence weak $\cdot 10^{-3}$) | 1.4 | 1.5 | 1.6 | 1.9 | 1.7 | 1.8 | 2.1 | 2.3 | 2.19 | 2.4 | 2.6 | 3 |
| Fast fading (turbulence moderate) | 0.312 | 0.344 | 0.373 | 0.427 | 0.376 | 0.414 | 0.449 | 0.514 | 0.49 | 0.54 | 0.585 | 0.670 |
| Fast fading (turbulence strong) | 0.441 | 0.487 | 0.527 | 0.603 | 0.531 | 0.585 | 0.635 | 0.727 | 0.693 | 0.764 | 0.828 | 0.948 |
| **Effect of terrain profile**<br>Small city (1)<br>Medium city (2)<br>Large city (3) | <br><br>6.3<br>9.5<br>14.2 | <br><br>5.5<br>7.7<br>12.9 | <br><br>4.6<br>5.8<br>10.4 | <br><br>3.9<br>4.7<br>8.8 | <br><br>6.3<br>9.5<br>14.2 | <br><br>5.5<br>7.7<br>12.9 | <br><br>4.6<br>5.8<br>10.4 | <br><br>3.9<br>4.7<br>8.8 | <br><br>6.3<br>9.5<br>14.2 | <br><br>5.5<br>7.7<br>12.9 | <br><br>4.6<br>5.8<br>10.4 | <br><br>3.9<br>4.7<br>8.8 |

## References

[1] Blaunstein, N. and C. Christodoulou, *Radio Propagation and Adaptive Antennas for Wireless Communication Networks - Terrestrial, Atmospheric and Ionospheric* (2nd ed.), Wiley, New Jersey, 2014.